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BOTTOM POLE STRUCTURE WITH BACK-SIDE STEPS

by Kenichi Takano and Moris Dovek

FIELD OF THE INVENTION

The invention relates to the general field of magnetic write heads with particular reference to improving track density.

BACKGROUND OF THE INVENTION

To enable increases in the recording density achieved by a magnetic head, the coercivity of the recording media must be increased to overcome the demagnetization field of the magnetic transition. However as the track width decreases, so does the head field. When a high-end hard disk drive (HDD) generates a high data transfer rate, in the order of 1 Gbit/s, or more, not only is greater head field strength required, but there also is a need for a faster flux rise time. In order to achieve a large enough overwrite value, even in such high frequency conditions, the write current is boosted, giving its waveform a large overshoot. This often brings about severe excess saturation of the head and, as a result, adjacent track erasures often occur.

FIG. 1 is a schematic illustration of a conventional planar write head while FIG. 2

shows a closeup of the vicinity of the pole tip region. The design implements a bottom pole 11 (P1), pedestal 12 (P1P) and small throat height region 13 (for flux concentration), which opposes plane top pole 14 (P2)across from write gap 15. These poles are made of soft magnetic materials such as Ni, Co, Fe or their composites. The coil layer is packed onto the P1, and the P2 pole is fabricated on a planar surface to allow good track width control for the P2 tip width definition. The coil material is a non-magnetic conductor such Cu, Au, Al, Cr, Rh or their composite.

In a conventional planar write head, there are 3 kinds of flux leakage paths between the P1 and P2 pole at the air bearing surface (ABS), as shown is FIG. 3. Leakage path 31 is from P1 to P2, some of which contributes to writing on a magnetic medium. Leakage path 32 is flux flow from the P2 side to the P1 side wall. Leakage path 33 is flux from the P2 side wall to the P1P top boundary (P1 shoulder), because the P1 shoulder is coupled with the P2 side wall magnetically due to the structure. This flux path induces the concentration of the field just at the upper side of the P1 shoulder.

FIG. 4 shows cross track profiles 41- 45 of the in-plane field at the upper side of the P1 shoulder for write currents (Iw) of 10, 20, 30, 40, and 60 mA (curves 41-45 respectively). The x-axis down track corresponds to the position illustrated in the lower portion of the figure. This Pl shoulder field has greater strength than the gap side field (from the P2 side to P1 side wall), and grows with a shallow peak around the P1 shoulder corner,

from which the shoulder steps down gradually, as the write current increases. From this profile, the P1 shoulder field can become a possible source of erasures, not only at adjacent tracks but also at 2 or 3 tracks away.

The present invention discloses a way to remedy the undesirable problem of the P1 shoulder field in the high write current region.

A routine search of the prior art was performed with the following references of interest being found:

In US 6,657,816, Barr et al. teach a P1 pedestal on the read section while in 6,553,649, Santini shows recessing of the first pole. Cohen et al disclose etched regions around the first pole in US 5,995,342 while Sasaki describes recessed regions around P1 in US 6,317,289.

SUMMARY OF THE INVENTION

It has been an object of at least one embodiment of the present invention to provide a magnetic write head whose write width does not change significantly at high write

currents.

Another object of at least one embodiment of the present invention has been that said write head be able to tolerate severe excess saturation without causing any adjacent track erasure.

A further object of the invention has been to ensure that none of the flux generated during the write cycle, even at high write currents, finds its way to the P1 shoulder.

These objects have been achieved by dividing the bottom pole into front and rear sections with a step between them. The write gap is part of the front section while the rear section (to which the front section is attached) is closer to the top pole so, as one moves through the write gap, away from the ABS, there is a decrease in the reluctance between the top and bottom poles. As a result, excess flux generated by higher write currents can be absorbed directly behind the write gap in a direction normal to the ABS instead of being diverted to the bottom pole shoulder where it can do unintended writing on adjacent tracks.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1 and 2 show two views of a planar write head of the prior art.

FIG. 3 shows different leakage paths for the flux between P1 and P2.

FIG. 4 plots the write field (of a prior art device) as a function of distance from the write gap, illustrating how there is a peak in the vicinity of the P1 shoulder.

FIG. 5 shows a first embodiment of the invention, featuring a bottom pole that has front and rear sections, with the rear section being higher (closer to the top pole).

FIG. 6 plots the write field (of the invention) as a function of distance from the write gap, illustrating how there is virtually no peak in the vicinity of the P1 shoulder.

FIG. 7 compares the write current dependence of the write shoulder field for a prior art structure and for the invention.

FIG. 8 shows the normalized cross track profiles of the in-plane field at the write gap center for the prior art (curve 81) and invented (curve 82) devices.

FIGs. 9-12 illustrate four additional embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

We now disclose five embodiments of a P1 structure for a planar write head that remedies the undesirable problem of the P1 shoulder field in the high write current region. FIG. 5 shows an isometric view of a first embodiment of the invented structure. Top pole 54 includes end piece 52. This latter feature is optional (see embodiments 2, 3, and 5 below), the key feature of the invention being the introduction of a step between the front and rear portions of the lower pole as follows:

Referring briefly once more to FIG. 2, it can be seen that the prior art version of the lower pole comprises a flat layer 11 (typically between about 2 and 4.5 microns thick) that is covered by structure 12, the latter having opposing trapezoidal-shaped walls. Flux concentrator element 13 extends upwards from the top surface of 12 with its top surface defining the lower bound of the write gap. It is important to note that, at high write currents, the excess flux finds alternate paths to the side (33 in FIG. 3).

Returning now to FIG. 5, we continue our description of a first embodiment of the

invention. The bottom pole has been divided into front and rear sections with a step between them. The front section comprises the sub-structures 11 and 12 along with flux concentrator 13. The rear section (to which the front section is attached) is rectangular prism 51 whose top surface is higher than the top flat portion of element 12 (from which concentrator 13 upwardly extends). The top surface of concentrator 13 is higher than that of prism 51 and, furthermore, flux extender 53 runs from the inside edge of 51 all the way to the back edge of 51. So, as one moves through the write gap, away from the ABS, there is a decrease in the reluctance between the top and bottom poles, except in the write gap region itself. As a result, excess flux generated by higher write currents can be absorbed by the flux extender instead of being diverted to the side of the write gap.

The key dimensions that determine the performance of the device seen in FIG. 5 are as follows:

Top pole thickness (H1) -- between about 0.7 and 2 microns; thickness separating the trapezoidal walls of element 12 (H2) -- between about 0.3 and 1 microns; flux concentrator thickness (H3) -- between about 0.1 and 0.4 microns; flux extender thickness (H4) -- less than about 0.3 microns; distance flux extender extends from the flux concentrator (H5) -- between about 0.5 and 2 microns; thickness of top pole, including end piece 52 (H6) -- between about 0.7 and 2 microns; and height of rectangular prism (H7) -- between about 2 and 4.5 microns.

FIG. 6 is similar to FIG. 4 except that the data was taken from a device built according to the teachings of the present invention. It is readily seen that the P1 shoulder field decreases essentially monotonically with little or no peak appearing at the shoulder corner of the profiles and, also, the field value is lower than that of the prior art P1 shown in Figure 4. In particular, this improvement is most pronounced in the higher write current range.

As already noted, in a conventional structure, the P1 shoulder is magnetically coupled with P2, but in the invented structure, said coupling is to the back side step part of P1. So excess flux can mainly go through this step, and the flux density at the P1 shoulder remains low.

In FIG. 7, the write current dependence of the write shoulder field is compared for the prior art (curve 71) and invented (curve 72) structures. Since a recording medium typically has a coercivity of about 3-5,000 Oe, the leakage field of the prior art P1 might affect the recording medium's magnetization and introduce ATE (adjacent track erasure) problems. In contrast, the P1 field of the invention is low, being limited to about 2000 Oe, even for high write currents.

FIG. 8 shows the normalized cross track profiles of the in-plane field at the write gap center for the prior art (curve 81) and invented (curve 82) devices. Both profiles are

almost identical for cross track values up to 0.1 um, which corresponds to the track edge boundary, but, for cross track values greater than 0.1 um, the 'skirt' of the invented device is well attenuated. Consequently, the device of the invention provides better track width definition as well as good recording resolution, not only in the down track direction but also in the cross track direction.

It is important to note that many variations on the basic structure shown in FIG. 5 are possible while continuing to achieve the improvements in the write profile discussed above. Some possibilities are shown in the following examples.

2nd embodiment

This is illustrated in FIG. 9. This structure is similar to the first embodiment except that there is no end piece (element 52 in FIG. 5). The key dimensions that determine the performance of the device seen in FIG. 9 are as follows:

Top pole thickness (H1) – between about 0.7 and 2 microns; thickness separating the trapezoidal walls of element 12 (H2) – between about 0.3 and 1 microns; flux concentrator thickness (H3) – between about 0.1 and 0.4 microns; flux extender thickness (H4) -- less than about 0.3 microns; distance flux extender extends from the flux

concentrator (H5) -- between about 0.5 and 2 microns; and height of rectangular prism (H7) -- between about 2 and 4.5 microns.

3rd embodiment

This is illustrated in FIG. 10. This structure is similar to the second embodiment except that rectangular prism 99 does not extend all the way to the outer edge of flat layer 11. The key dimensions that determine the performance of the device seen in FIG. 9 are as follows:

Top pole thickness (H1) – between about 0.7 and 2 microns; thickness separating the trapezoidal walls of element 12 (H2) -- between about 0.3 and 1 microns; flux concentrator thickness (H3) – between about 0.1 and 0.4 microns; flux extender thickness (H4) -- less than about 0.3 microns; distance flux extender extends from the flux concentrator (H5) -- between about 0.5 and 1.5 microns; and height of rectangular prism (H7) -- between about 2 and 4.5 microns.

4th embodiment

This is illustrated in FIG. 11 and is a hybrid of the first and third embodiments (includes an end piece and has a reduced width for the rectangular prism portion). The key dimensions that determine the performance of the device seen in FIG. 5 are as follows:

Top pole thickness (H1) – between about 0.7 and 2 microns; thickness separating the trapezoidal walls of element 12 (H2) – between about 0.3 and 1 microns; flux concentrator thickness (H3) – between about 0.1 and 0.4 microns; flux extender thickness (H4) -- less than about 0.3 microns; distance flux extender extends from the flux concentrator (H5) – between about 0.5 and 1.5 microns; thickness of top pole, including end piece 52 (H6) – between about 0.7 and 2 microns; and height of rectangular prism (H7) -- between about 2 and 4.5 microns.

5th embodiment

This is illustrated in FIG. 12 and is similar to the third embodiment except that the top surface of flux concentrator 13 is coplanar with that of rectangular prism 99 so there is no flux extender element. The key dimensions that determine the performance of the

device seen in FIG. 9 are as follows:

Top pole thickness (H1) -- between about 0.7 and 2 microns; thickness separating the trapezoidal walls of element 12 (H2) -- between about 0.3 and 1 microns; flux concentrator thickness (H3) -- between about 0.3 and 0.4 microns; and height of rectangular prism (H7) -- between about 2 and 4.5 microns.

What is claimed is: